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A web-platform for linking IFC to external information during the entire lifecycle of a building

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Abstract

During the lifecycle of a building, much more information is used and produced than can be contained inside a Building Information Model (BIM). The information outside the BIM is seldom connected to the BIM or connected across domains. Furthermore, information in BIM is only accessible to people with sufficient CAD or architectural background, and often expensive software is needed to edit and add data. This inefficient information management causes significant costs in practice. Our research contributes to the development of IFC based web applications in practice and demonstrates a way of linking machine to human readable data thus making the data accessible to non CAD users or architectural experts. In this paper we describe such a platform for the integration of model-based data and non-model based data. We tried to construct a mapping process from IFC properties to a national building element classification system, as a way of structuring the objects and information for use in our web platform. Since both the structure of IFC and most building element classification systems are based on semantic relations of building elements (i.e. holonym, meronym, hypernym), translations by means of a basic reasoning system should be feasible. We elaborate on several uses of this platform in applications for maintenance and reuse of building materials, buildings and built structures.

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Keywords: Industry foundation classes (IFC); re-use of materials and building components; building maintenance; semantic web; BIM; Linked Data

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1. Introduction

Nowadays, openBIM collaboration in the building industry is gaining momentum. Architects, contractors and subcontractors are exchanging building information through the international openBIM IFC standard. Although more and more non-geometric data is added to the models, exchanged files are mainly used for coordination of geometric issues like clash-control and exports for quantity takeoff.

However, the participants in the building process use and produce much more information than can be contained inside a Building Information Model (BIM) as it is being used in practice. Cost estimation, planning, management workflow, brief information, and product specifications are but a few examples of information being exchanged throughout the building process outside the model. Within the operational phase of a building, even more information is being produced, for example, maintenance data, energy use, occupancy patterns, etc.[1] All this information and the BIM are usually stored locally and shared via email, or project management systems on a need to know basis, and seldom connected across domains. Also, information generated outside the model based on exports of for instance quantity takeoff is seldom fed back into the model (see Fig. 1). This inefficient information management causes significant costs.[2,3]

Two problems contribute to inefficient information management: accessibility of the information and differences in expertise. First, information in the BIM is only accessible to people with sufficient CAD background and usually expensive software is needed to edit and add data. Second, the differences in expertise are well described in the work of Sattineni & Bradford[4] in 2011: "Most organizations reported that employees skilled in BIM did not have the estimating experience to produce working estimates from BIM models and vice-versa" (p. 564) According to this study, employees are mostly either CAD/BIM proficient, or experts in other fields like cost estimation.

The BIM is more and more the central point of the information used in the building process, and much effort is put into using BIM during the operational phase of the building. Information outside the BIM is usually not connected to the relevant elements inside the BIM. In practice, connections between this types of information are usually made (semi-)manual through adding national building element classifications (such as NLSfB or Unicode), and exporting information to Excel or other software. Adding such classifications as data to the model is often demanded in BIM-protocols, but is not very efficient.

Since both the structure of IFC and most building element classification systems are based on semantic relations of building elements (i.e. holonym, meronym, hypernym), mappings by means of a basic reasoning system seem like a logical step. We created mappings from IFC object properties to the Dutch NLSfB code, which can then be used to automatically classify objects in the system, and link them to cost databases, which are structured along these classifications.

Linking the data in the BIM to an external database of connected cross-domain information and a web platform for querying, viewing, editing, and adding information may solve the problems mentioned above[5], as "Each human domain expert is only able to master a certain field of expertise. Only from the synergetic effects of collaborative efforts will the larger problem or engineering challenge be solved."[6].

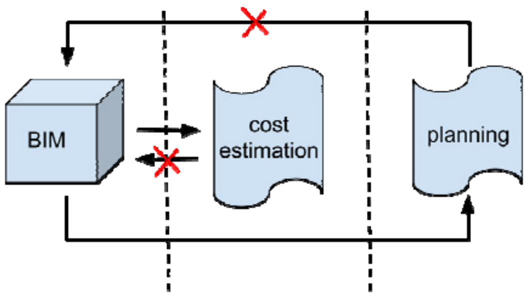


Fig. 1. Information from the model is being exported for use in other domains, but not integrated back into the model.

1.1. Possible Uses

A platform where objects in a BIM have their own linked web page with all relevant information can be used throughout the building process. Such a platform has the potential to become an easily accessible central point of information about the building for all stakeholders in the process, capable of storing, editing and retrieving information throughout, and after the lifecycle of a building. It has the capacity of 'closing the circle' of material use in the building industry, because for efficient reuse of building parts after demolition, their properties and state must be known.[7] Furthermore, easy access to this building information is crucial for adapting existing buildings to current demands.[8]

In the field there are several developments, for instance the DURAARK project, which could build upon a flexible web platform linking model data to non-model data, for use in long-term storage of building information. Two applications that we are currently developing could be based upon this platform:

- BIMit (http://bimit.nl - available from august 2014) is a web application for viewing BIM data and linking BIM data by an IFC property to content. By these means a Content Management System becomes a Building Management System where all documents, discussions, calculations, calendars, workflows and non-geometry specific data are managed and represented through customizable interfaces. We envision this application as the central point where all data about the building is being stored, used, structured and updated, from first concept to demolition. BIMit will be offered commercially as Software as a Service.

- Creation2Creation (C2C) Site and C2C App, the C2C Site is a social networking service aimed at designers and makers, with the purpose of recycling (building) materials that become available through demolition or remain unused at a construction site. C2C App is an app where objects which are free for reuse can be photographed or 3D-scanned, and offered for reuse through the Creation2Creation site. These applications are still in concept phase, but are envisioned as a logical follow up of the development of BIMit, because they use similar techniques to BIMit, especially in the usage of RDF and searchability of building materials on the web.

1.2. Building Management System

As the development of the Content Management System made it possible for people who cannot write HTML to deliver content to the web, we aim to open up the information in the BIM to people who are not able to use BIM software. In this paper we will refer to our system as a Building Management System (BMS) in a broader definition than currently used. Besides its normal meaning of controlling sensors and actors of the building internal systems, a BMS as we see it stores and manages all building related data.

2. Description of the platform

Linking the data in the BIM to an external database of connected cross-domain information and a web platform is a way of opening up this information to users without CAD knowledge and software. Below, we describe such a platform for the integration of model-based data and non-model based data.

2.1. Components of the platform

According to our observations, IFC is the most commonly used open standard for model exchange in the building industry. It can be exported and imported in all of the most used BIM software. At the moment there are several proprietary systems available for storage and sharing of building information models. Some can handle IFC files, others are linked to the native file formats of modeling software like Archicad or Revit. Most are capable of creating links to information stored outside the model, but they are either limited to the use of native modeling software, or the licensing costs are very high for small and medium enterprises which compose a large part of the building industry.

Apart from these proprietary systems, there are also open source developments, the main one being the Open Source BIMserver[9] (hereafter referred to as BIMserver), as developed by TNO en TU/e. Since its publication in 2010 it has kept developing and there is now an active community building not only the BIMserver but also an ecosystem of open source BIM applications through the Open Source BIM collective (http://opensourcebim.org). Since it is well-documented and easy to expand or connect to, building a system as extension to BIMserver is a logical step in developing our web platform and linking models to external information.

The foundation of the platform is the BIMserver, which is then linked to a Content Management System. As a content management system we have decided to use Drupal (http://drupal.org), an open source content management platform which is very flexible, extendable, secure and suited to large and complex sites. Drupal also has a large community developing the core, as well as building new components called modules.

2.2. MVC backbone.js

Due to the nature of on-screen visualization of 3D geometric data which results in high data traffic and processing requirements of the end user system, we want to reduce the amount of page reloads. We chose to implement a Model View Controller (MVC); backbone.js (http://backbonejs.org/). This enables us to have dynamic editing capabilities without reloading the model. Another great advantage is that we can utilize the data sets to dynamically generate graphs and overview spreadsheet functionality without duplicating the data.

2.3. Linking Drupal to the BIMserver

The only thing we add to the model is a link to the BMS entity. We add this link as a way to enrich the model with other metadata, subsystems and logic without polluting the IFC model. An object in IFC stored in the BIMserver is linked by its GUID, commonly known as the BIMid, to an entity in our Building Management System (BMS). Information about this object (or a group of objects) can then be stored, viewed and edited in the BMS, while remaining linked to the object in the original IFC file (see Fig. 2).

One or more data objects in the BIMserver are connected to one or more Drupal entities. These entities in the database are identified and linked to their original objects in the BIMserver by their GUID's. For each entity in the database, a web endpoint is then shown and populated with the desired properties from the IFC. Such pages can also be automatically created for groupings of objects by parameter. Each endpoint has the option of adding attached elements like lists, documents, pictures, notes calculations, charts, diagrams, pictures etc.

Revision tracking is implemented throughout the platform, for all entities and linked elements, geometry revisions are tracked by BIMserver. By utilizing two revision systems we are able to track geometric and logic revisions in the relation they have to each other. If the IFC file is exported from the BIMserver to be used in another application (for example; an architect designing an extension of the building in BIM-modeling software) the link to the BMS and thus all related information remains available in the other piece of software. IFC's can be uploaded into the BIMserver via the BMS (see Fig. 3) or CAD software can communicate with BIMserver via a proxy.

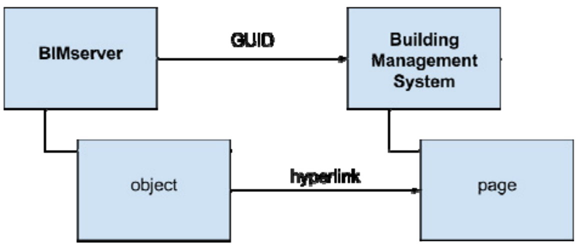


Fig. 2. Linking BIMserver to the BMS.

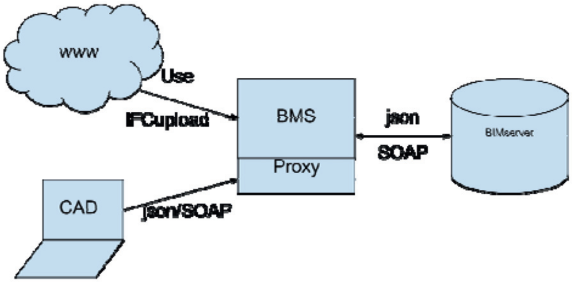


Fig. 3. Diagram of the structure of our platform.

2.4. Visualization

For BIMserver management we include bimvie.ws (bimvie.ws) as our interface (see Fig. 4). We also use Bimsurfer as an open source WebGL viewer (bimsurfer.org). The objects can be selected and queried exposing the properties on which the BMS logic is linked. We utilize the view generated for all BIM related data in the MVC thus enabling to have dynamic updates in the BMS whenever the model changes in BIMserver. This also enables the model to become context aware so it is able to adapt to changing end user situations. In this way the information presented to the user is adapted to the role of the end user in the building process, for instance a cost estimator needs different information about the objects than an architect.

2.5. XML parser

In our platform, information is represented in many different ways. For data exchange with other systems XML is most commonly used. An XML parser as a Drupal module was created in order to import complex datasets in the BMS. For this, the Drupal feeds module was used (drupal.org/project/feeds). After choosing an XML schema (XSD file), the data is parsed to data store, where the module is able to handle multiple attribute values. Fig. 5 describes the parsing process. The module is aware of the presented and structured data store and is currently able to cascade underlying XML structures. When the module is validated it will be published on Drupal.org.

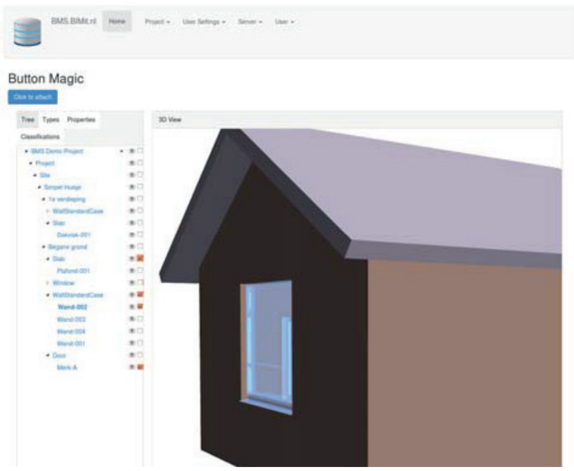
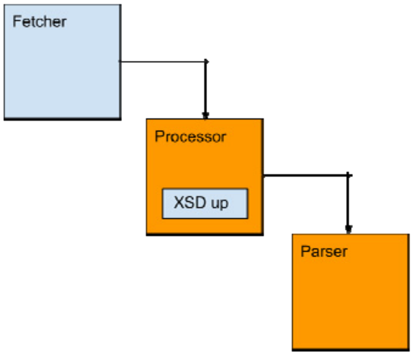


Fig. 4. Prototype screenshot.



1. XSD file upload
2. Process XSD
3. Data store:
   a | tuple namespace
   b | tuple value
   c | attribute namespace
   d | attribute value
4. Provide Mapping in the parser by sorting all tuple and attribute namespaces hierarchically
5. Mapping is manual or by means of features module.

Fig. 5. Structure of the XML parser.

2.6. Semantic web

The use of Semantic Web for the building industry has been the subject of several studies in recent years. Results indicate that adding semantic data to building objects in BIM has the following uses:

- It can help bridge the gap between domains in the building industry[10,11,1,12,13],
- It can be used for rule checking applications[14],
- It can be used for querying the model for information[10],
- It enables a link between different national concept libraries which are under development into a larger system[15]

For our web platform, it makes sense to implement these semantic structures into the information linked to the model. Recent work by Beetz et al.[11] has demonstrated the uses of adding these semantic information straight into the IFC model. This could be beneficial as the information becomes available to all applications using the model. However, we have chosen not to enrich the model other than adding a hyperlink for every object, since data in a web database is much easier to update to a new or updated concept library then tags in a IFC property. The page where the hyperlink leads then contains human and machine readable data, structured as html with RDF tags describing the objects on the page. In this way, the semantic web becomes the third and top-layer of our platform, as seen in Fig. 6.

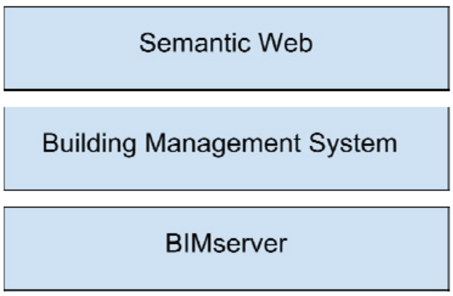


Fig. 6. Layers of the web platform.

Table 1. Four-number NLSfB codes for external walls with translations of the Dutch descriptions.

NLSfB code	Dutch description	English translation of Dutch description
21	BUITENWANDEN	External walls
21.0	ALGEMEEN	General
21.1	NIET CONSTRUCTIEF	Non-loadbearing
21.10	ALGEMEEN	General (use of this code is usually discouraged in practice)
21.11	MASSIEVE WANDEN	Solid non-loadbearing external walls
21.12	SPOUWWANDEN	Non-loadbearing external cavity walls
21.13	SYSTEEMWANDEN	Non-loadbearing external system walls (for instance wood framing)
21.14	VLIESWANDEN	Curtain walls
21.15	BORSTWERINGEN	Balustrade (as part of a non-loadbearing wall)
21.16	BOEIBOORDEN	Fascia board
21.17	SCHOORSTENEN/KANALEN (BOUWKUNDIG)	Chimneys (built as a wall)
21.2	CONSTRUCTIEF	Loadbearing
21.20	ALGEMEEN	General (use of this code is usually discouraged in practice)
21.21	MASSIEVE WANDEN	Solid loadbearing external walls
21.22	SPOUWWANDEN	Loadbearing external cavity walls
21.23	SYSTEEMWANDEN	Loadbearing external system walls (for instance wood framing)
21.25	BORSTWERINGEN	Balustrade (as part of a loadbearing wall)

2.7. Semantic web

As a part of the platform, an automatic mapping of IFC properties to the Dutch NLSfB codes upon import of IFC files was planned. In this way the model is prepared for links to cost databases[12]. We decided to focus on mapping elements in the architectural domain. Numbers over 50 than in the NLSfB code belong to the HVAC/MEP domain, in which we have little expertise. As an illustration of the four-number codes, a small excerpt of the codes (for external walls) with translation for the descriptions can be seen below in Table 1.

The four-number code can be mapped from just a few properties of IFC objects, which are listed below:

- 1 = IfcElement, for instance IfcWall, IfcSlab, and IfcFooting
- 2 = Loadbearing (TRUE/FALSE)
- 3 = IsExternal (TRUE/FALSE)
- 4 = IfcElementTypeEnumeratedValue - subclassification of IfcElements; for instance IfcFooting has enumerated values FOOTING_BEAM, PAD_FOOTING, PILE_CAP, STRIP_FOOTING, USERDEFINED, NOTDEFINED
- 5 = IfcNoOfLayers - returns the number of layers from the material description attached to an element

An example of mapping is “22.21 MASSIEVE WANDEN” = A solid loadbearing internal wall. This means that the object:

- is an IfcWall or IfcWallStandardCase,
- has the value of loadbearing: TRUE,
- has the value of IsExternal: FALSE, and

- has IfcNoOfLayers, which in this case returns the value 1.

Table 2. Successful mapping of footing elements.

NLSfB code	Dutch description	English translation	IfcElement	EnumeratedValue	Loadbearing	IsExternal
16.11	FUNDATIE VOETEN	Strip footing	IfcFooting	strip_footing	TRUE	TRUE
16.12	FUNDATIE BALKEN	Footing beam	IfcFooting	footing_beam	TRUE	TRUE
16.13	FUNDATIE POEREN	Pad footing	IfcFooting	pad_footing	TRUE	TRUE

Table 3. Successful mapping of stair elements.

NLSfB code	Dutch description	English translation	IfcElement	EnumeratedValue
24.10	ALGEMEEN	General	IfcStair	NotDefined
24.11	RECHTE STEEKTRAPPEN	Straight run stairs	IfcStair	StraightRunStair
24.12	NIET RECHTE STEEKTRAPPEN	Non straight run stairs	IfcStair	≠24.10, 24.11, 24.13
24.13	SPILTRAPPEN	Spiral stairs	IfcStair	SpiralStair
24.15	BORDESSEN	Landing	IfcSlab	Landing

Table 4. Unsuccessful mapping of loadbearing slab types (italic represents unsuccessful).

NLSfB code	Dutch description	English translation	IfcElement	EnumeratedValue	loadbearing
23.21	VRIJDRAGENDE VLOEREN	Free spanning floor	IfcSlab	Floor	TRUE
23.22	*BALKONS*	Balcony	IfcSlab	Floor	TRUE
23.23	*GALERIJEN*	Gallery	IfcSlab	Floor	
23.24	*BORDESSEN*	Landing	IfcSlab	Landing	
23.25	*VLOEREN T.B.V. TECHNISCHE VOORZIENINGEN*	Floors for technical services	IfcSlab	Floor	

Another example is “21.22 SPOUWWANDEN” = A loadbearing external cavity wall. This means that the object:

- is an IfcWall or IfcWallStandardCase,
- has the value of loadbearing: TRUE,
- has the value of IsExternal: TRUE, and
- has IfcNoOfLayers, which in this case returns a value of more than 2.

In contrast to our original expectations, we were not successful in creating a full mapping. The reason for this is that not all NLSfB entities can be easily mapped to properties of IFC objects. A few examples of these mappings can be seen in Table 2-4. Many classifications in the NLSfB code are dependent on the function, position or construction method of the element, which cannot be determined from basic IFC properties. Table 4 shows a conflict in classifying landings: 23.24 has the same properties as 24.15 in Table 3. A few extra examples are:

- an IfcSlab which is outside the building shell can be both a balcony and a gallery
- an IfcCovering with subtype ceiling can have 9 different classifications, dependent on the way the ceiling is constructed, and how it is positioned (against the underside of the floor slab or with a plenum)
- an IfcWindow or IfcDoor as exported from much-used modeling software like Archicad or Revit is just a ‘dumb’ object with BREP geometry. None of the advanced possibilities available in these IFC elements is implemented in the IFC exporters of these software.

3. Conclusion

In this paper, we have described a way of linking the data in BIM to an external database of connected cross-domain information and a web platform. A platform like this will enable non-CAD-users to access the data in the BIM, and in this way connect experts to the information they need.

Linking the model information to other data sets like cost estimation automatically can be done through mapping object properties from the model to national building classifications like NLSfB. Our attempt to create such a mapping structure was not successful, but a further attempt, using more properties of the object and spatial relations to other objects could be successful. We would welcome any input from the DDSS community on this point, and will gladly cooperate to make this mapping possible. However, this mapping function is probably more versatile and useful as a BIMserver plugin then as a part of our web platform.

4. Further research

For the semantic enrichment of our system, a decision needs to be made regarding which concept libraries to use. Because we anticipate the arrival of CB-NL concept library and an open publication of the NLSfB as an OWL, we would like our own platform-specific concepts to be part of a larger system[15]. Because such a system and CB-NL is still in a conceptual stage, we will try to implement semantic concepts as far as they are available right now. Other semantic technologies will be implemented when they are more mature and increase collaboration.

Since the web platform is capable of linking documents and models, it would be conceivable to make this system OAIS compliant, as described by Lavoie[16] in 2004. In this way, the web platform could be used as a system for long term storage as planned by the DURAARK project[8]. We think that since the model and linked information remain "live" data during the entire lifecycle of a building, the system will be constantly adapted to new technologies and there will be no "legacy" data in the system which needs representation information. However, adding such data to the system is easy, and export of an OIAS compliant submission information package (SIP) is also easily implemented.

Combining our platform's capabilities to the research in semantic rule checking environments[14] would extend the reach and use of the platform into checking building regulations and many other functions that now need software like Solibri to be performed.

Acknowledgements

We would like to recommend that anyone considering research into BIM for existing buildings starts reading the excellent paper by Volk et al.[17] in 2014: "Building Information Models (BIM) for existing buildings – literature review and future needs" - which is a very good starting point in getting up to date in the current state of research in the field.

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